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Technical Note N-1096

CORROSION OF DSRV MATERIALS IN SEA WATER - 12 MONTHS NATURAL EXPOSURE AND 98 CYCLES IN PRESSURE VESSELS

By

Fred M. Reinhart and James F. Jenkins

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NAVAL CIVIL ENGINEERING LABORATORY
Port Hueneme, California 93041

CORROSION OF DSRV MATERIALS IN SEA WATER - 12 MONTHS NATURAL EXPOSURE AND 98 CYCLES IN PRESSURE VESSELS

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52-003

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ABSTRACT

In order to evaluate specific corrosion problems involved in the design of the DSRV (Deep Submergence Rescue Vessel), a corrosion test program was initiated to determine: (1) the effects of galvanic and crevice corrosion on selected combinations of metals, and (2) the efficacy of selected paint coatings, sealing compounds and galvanic anodes for mitigating corrosion, crevice corrosion and galvanic corrosion. Composite specimens representative of proposed DSRV construction materials and methods were exposed for 370 days at mean tide level in sea water and to cyclic exposure to pressurized sea water. This report presents an evaluation of these composite specimens after exposure.

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INTRODUCTION

In the design of the Deep Submergence Rescue Vessel (DSRV) for the U. S. Navy Deep Submergence Systems Project, Lockheed Missile and Space Corporation selected many different metals for use throughout the DSRV because of their desirable mechanical or physical properties. The corrosion behaviour of such multicomponent systems when immersed in sea water was, however, unknown. In order to determine the magnitude of corrosion attack on the metal combinations specified for use in the DSRV and to determine the efficacy of proposed corrosion mitigation methods, a sea water test program was initiated to determine:

1. The effects of galvanic corrosion on combinations of alloys representative of those found on the DSRV.

2. The efficacy of various sealing compounds in preventing crevice corrosion.

3. The efficacy of paint coatings for preventing galvanic corrosion.

4. The efficacy of galvanic anodes in preventing corrosion, galvanic corrosion and crevice corrosion of dissimilar metal combinations.

Specimens designed to evaluate the four areas of interest noted above were exposed at mean tide level at the Point Mugu site for a period of one year. The specimens were nominally 6x12 inches. Some of the specimens (the G-series) had 1x5-inch strips attached as shown in Figure 1. Sealants to be tested were applied at the faying surfaces between the panel and strips and on the heads of the fasteners. The types of fasteners used, the composition of the panel and strips, the paint coatings and sealants, where used, are given in the specimen descriptions in Table 1. At mean tide level the specimens are immersed in the sea water at high tide and exposed to the sea air at low tide. The geographical location and sea water characteristics at the Point Mugu site are:

Latitude, North	34°06'
Longitude, West	119°07'
Temperature, °C	12-19
Oxygen, ml/l	3.9-6.6
Salinity o/oo	33.51
pH	8.1
Current, Knots	Variable

This report discusses the results obtained after 371 days of exposure at mean tide level.

Replicate specimens of special interest were exposed to pressurized sea water under conditions of cyclic loading simulating the operation of the DSRV. The specimens were placed in a pressure vessel, the vessel was filled with sea water and pressurized to 3,000 psi and held for 7 hours. The pressure was then released, the vessel drained and the specimens allowed to remain inside the closed vessel exposed to the damp atmosphere for 17 hours, after which the pressurization cycle was repeated. The vessel was depressurized and drained over weekends and holidays. The characteristics of the sea water used to fill the pressure vessel and of the effluent after 7 hours of pressurization are shown below.

	Input			Effluent		
	max	avg	min	max	avg	min
Temp., °C	21.1	15.4	14.1	25.4	17.5	10.0
Oxygen, ml/l	6.47	5.54	3.67	5.41	4.16	2.57
Salinity, o/oo	32.43	31.72	30.56	NOT ANALYZED		
pH	7.63	7.43	7.30	7.65	7.44	7.14

This report discusses the results obtained after 98 cycles of pressurization.

RESULTS AND DISCUSSION

Tidal Zone Exposure

The specimens exposed at mean tide level, their component parts, the protective systems, the sealing compounds for filling crevices and coating fasteners, and the results of visual examinations after exposure are given in Table 1. Each specimen is discussed below.

Specimen G1C. The specimen was heavily fouled with barnacles, mussels and tube worms.

The paint had failed along the edges of the panel and strips in a few areas and had failed on the surfaces of strip numbers 1, 2, 4, 5 and 6.

There was no paint or sealant failure at the strip-panel faying surface between the panel and strips which resulted in any noticeable corrosion. Sealants DC-780 and PR-1532 showed good adhesion at the faying surfaces while DC-93046 showed only moderate adhesion at the faying surfaces, and DC-11 and sprayed PVC sealant showed little or no adhesion at the faying surfaces. The DC-93046, DC-11, and sprayed PVC sealants had failed on the heads and nuts of the fasteners on their respective strips. The heads of the 6061-T6 aluminum alloy fasteners under the DC-93046 sealant were severely pitted.

The cadmium plated steel washers used under the nuts on this panel were slightly corroded where they were uncoated or coated with DC-93046, DC-11 or sprayed PVC sealants. Electrical measurements showed that there was a low resistance electrical path between the cadmium plated steel and the aluminum alloy fasteners, but there was a very high electrical resistance between the fasteners and the panel or their respective strips. Thus, when the washers were exposed to the sea water due to sealant failure the cadmium plating would soon be consumed by galvanic corrosion, and afterward the exposed steel would cause galvanic corrosion of the 6061-T6 fasteners with which it was electrically connected. The steel would, however, continue to corrode, although at a reduced rate, because the 6061-T6 fasteners could not afford complete galvanic protection of the steel; i.e., there were still anodic areas of steel present.

Specimen G2C. The specimen was heavily fouled with barnacles, mussels and tube worms.

The paint had failed along the edges of the panel and strip #6, especially at the areas of the panel in contact with the mounting insulators. The topcoat paint had peeled from a small area of strip #1.

There was no failure of the paint or sealant at the strip-panel faying surface which resulted in any noticeable corrosion. However, sea water had penetrated up to 1/4 inch under the strip with DC-93046 sealant. Sealants PR-1527 and PR-1422 showed excellent adhesion at the faying surfaces while DC-93046 showed moderate adhesion and sealants DC-11 and sprayed PVC showed little or no adhesion. The PR-1422, DC-93046, DC-11 and sprayed PVC sealants had failed at the heads and backs of the 5052 aluminum alloy rivets used to fasten the strips to the panel. The rivets under the failed DC-93046 sealant were badly pitted as shown in Figure 2. There was no corrosion of the other fasteners on this panel.

Specimen G3C. The specimen was heavily fouled with barnacles, mussels and tube worms.

The paint had failed on the panel at the corners and under the mounting insulators. There was pitting at areas of exposed bare metal at these paint failures. There was blistering of the paint on the back of the panel at the fasteners of strips #1, 4, 5 and 6 with pitting around the fasteners on strip #4. There were paint failures at the corners and blistering adjacent to the fasteners on strips #1, 4, 5 and 6 with pitting at the corners of strip #4.

Sealants DC-780, PR-1532, DC-93046, DC-11 and sprayed PVC had failed at the fasteners. There was evidence of sea water penetration along the fasteners on the strip without sealant and with sealants DC-780, PR-1532, DC-93046, DC-11 and sprayed PVC. There was evidence of sea water penetration and corrosion at the faying surfaces of the strips without sealant and with sealant DC-93046, especially near the fasteners. Sealants DC-780, PR-1532 and DC-93046 showed good adhesion at the faying surfaces. Sealants DC-11 and sprayed PVC showed little or no adhesion.

There was no corrosion of the A-286 fasteners, although they seem to have accelerated the corrosion of the aluminum alloy panel at areas where the paint was damaged by their placement. Paint blistering also seemed to be accelerated near the A-286 fasteners.

Specimen G4C. The specimen was heavily fouled with barnacles, mussels and tube worms.

The top coat of paint had peeled in many areas on the panel and there were paint failures to bare metal with pitting underneath on the edges of the panel. The paint had failed along the edges of the strips.

Sealant PR-1527 was intact under its protective sleeve but had failed at the heads of the fasteners. Sealants PR-1422, DC-93046, DC-11 and sprayed PVC had failed at the fasteners. There were no sealant failures at the faying surfaces. Sealants PR-1527, PR-1422 and DC-93046 showed good adhesion at the faying surfaces whereas sealants DC-11 and sprayed PVC showed little or no adhesion at the faying surfaces. There was no corrosion of the titanium alloy fasteners; however, the anodized aluminum alloy washers used with these fasteners were covered with white corrosion products.

Specimen G5C. The specimen was heavily fouled with barnacles, mussels and tube worms.

The paint had failed along the edges of the panel and under the mounting insulators. There was severe pitting of the panel under areas of paint failure to bare metal. There was paint blistering of the panel adjacent to strip #1 with pitting underneath. The paint had also failed along the edges of the strips and adjacent to the bolt holes on strip #1. There were white corrosion products in the bolt holes on strip #1.

The DC-780, PR-1532, DC-93046, DC-11 and sprayed PVC sealants had failed and allowed rusting of the cadmium plated steel washers. Sealants DC-780, PR-1532 and DC-93046 showed good adhesion at the faying surfaces. Sealants DC-11 and sprayed PVC showed little or no adhesion at the faying surfaces.

The A-286 fasteners were uncorroded. The cadmium plated steel washers used with the A-286 fasteners were moderately corroded.

Specimen G8C. The specimen was moderately fouled with barnacles, mussels and tube worms.

The anodized coating was nearly gone from the exposed areas of the panel and strips. The exposed areas of the panel and strips had an etched appearance. The anodized coating under the strips and anode was virtually intact except for small areas up to 1/4 inch wide where the sea water had penetrated under the edges of the strips.

The nickel-copper 400 and type 304 stainelss steel rivets were uncorroded.

The zinc anode was approximately 5% consumed and had a noticeable groove next to the panel.

Specimen G8G. The specimen was moderately fouled with barnacles, mussels and tube worms.

The panel was etched but uncorroded. The titanium alloy strips were uncorroded. The type 304 stainless steel and nickel-copper 400 alloy rivets were uncorroded. There was a thin layer of white corrosion products at the panel-strip faying surfaces and the panel was etched at these surfaces. The zinc anode was 10% consumed and had a slight groove next to the panel. There was no corrosion of the panel under the anode.

Specimen G9C. The specimen was heavily fouled with barnacles, mussels and tube worms.

There were a few paint failures along the edges of the panel. The DC-780 sealant had failed on the heads and nuts of the fasteners but remained intact with good adhesion at the faying surfaces. The fasteners were rust stained but showed no noticeable pitting. The strip-panel faying surfaces were uncorroded.

Specimen #2. The specimen was heavily fouled with barnacles, mussels and tube worms but was uncorroded. The galvalum anode was slightly pitted. The weld beads and heat affected zones were unattacked.

Specimen #4. The specimen was heavily fouled with barnacles, mussels and tube worms but was uncorroded. The galvalum anode was slightly pitted. The weld bead and heat affected zones were unattacked.

Specimen #6. The specimen was heavily fouled with barnacles, mussels and tube worms but was uncorroded. The galvalum anode was 90% consumed. The weld bead and heat affected zones were unattacked.

Specimen #7. The specimen was heavily fouled with barnacles, mussels and tube worms but was uncorroded. The galvalum anode was 90% consumed. The weld bead and heat affected zones were unattacked.

Specimen #8. The specimen was heavily fouled with barnacles, mussels and tube worms.

There were paint failures along the bottom edge of the panel with attendant corrosion. There was no blistering or paint failures at the scribe marks.

Specimen #9. The specimen was heavily fouled with barnacles, mussels and tube worms.

There were paint failures from abrasion along the bottom edge of the panel without attendant corrosion. There was no corrosion or paint failures at the scribe marks.

Specimen #12. The specimen was heavily fouled with barnacles, mussels and tube worms.

There were a few paint failures with rusting along the edges of the panel. There were a few paint failures on the surface of the panel on the side with scribe marks and some blistering and rust staining at the scribe marks.

Specimen #13. The specimen was heavily fouled with barnacles, mussels and tube worms.

There were a few paint failures with attendant rusting along the edges of the panel and on the surfaces of the panel and at the scribe marks.

Pressure Vessel Test

The specimens exposed to cyclic pressure loading in sea water, their component parts, the protective systems, the sealing compounds for filling crevices and coating fasteners, and the results of visual examinations after exposure are given in Table 2. Each specimen is discussed below.

Specimen G1D. The specimen was covered with superficial rust stains. There were no paint failures on the panel or on the attached strips. There were no failures of the sealants at the strip-panel faying surfaces. Sealants DC-93046 and sprayed PVC had failed on the heads of the fasteners and had allowed some light corrosion of the fasteners.

Specimen G2D. The specimen was covered with superficial rust stains. There were two areas of paint abrasion at the lower corners of the panel but there was no corrosion of the panel at these paint failures. These failures resulted from abrasion during loading of the specimens into the pressure vessel. There were no other paint failures on the panel or attached strips. There were no sealant failures at the panel-strip faying surfaces or on the fasteners. The top coat of paint peeled from the panel beneath the strips which were sealed with PR-1527, PR-1422 and DC-93046; the other sealants had little or no adhesion.

Specimen G3D. The specimen was covered with superficial rust stains. There was one area of paint failure with light underlying corrosion where the paint was abraded from the panel by contact with the pressure vessel. The underlying corrosion was attributed primarily to contact with the steel interior of the pressure vessel. There were no other paint failures on the panel or attached strips. The DC-780, DC-93046 and sprayed PVC sealants failed at the fasteners. There was no corrosion of the fasteners; however, white corrosion products on the sleeves of the fasteners sealed with DC-780, PR-1532, DC-93046 and sprayed PVC indicated that moisture had penetrated to the sleeve-panel interface. The water repellent character of DC-11 sealant prevented this penetration of moisture, but did not protect the heads of the fasteners.

Specimen G4D. The specimen was covered with superficial rust stains. There were no paint failures on the panel or attached strips. Sealants PR-1422, DC-93046, DC-11 and sprayed PVC failed at the fasteners. There were no sealant failures at the faying surfaces.

There was no corrosion of the fasteners but there were white corrosion products on the washers under sealant failures or on unsealed fasteners. There were no sealant failures at the panel-strip interface. However, the top coat of paint peeled from the panel on the strips sealed with PR-1527, PR-1422 and DC-93046 sealants. The other sealants had little or no adhesion.

Specimen G5D. The specimen was covered with superficial rust stains. There were no paint failures on the panel or strips except at the unused fastener holes between strips #1 and #2. The DC-780, PR-1532, DC-93046 and sprayed PVC failed at the fasteners and allowed the cadmium plated steel washers to corrode. There was no attack on the A-286 fasteners. The sealants did not fail at the panel-strip faying surfaces.

Specimen G8D. The specimen was covered with superficial rust stains. There was some pitting at the corners of the panel and on the attached strips as shown in Figure 3. This attack occurred during cycles 1 through 10 when the panel was in contact with the sides of the pressure vessel. The attack did not increase after the panel was insulated from further contact with the sides of the pressure vessel. The fasteners were uncorroded. There was a light film of corrosion at the faying surfaces indicating the inability of the zinc anode to completely prevent crevice corrosion. The zinc anode showed no visible consumption.

Specimen G8H. The specimen was covered with superficial rust stains. The panel and strips were uncorroded except for incipient crevice corrosion at the panel-strip interface. The type 304 stainless steel and nickel-copper 400 alloy rivets were uncorroded. There was no visible consumption of the zinc anode.

Specimen G9D. The specimen was covered with superficial rust stains. The DC-780 sealant and paint system did not fail. The fasteners were uncorroded. The delrin strips, sleeves and washers effectively eliminated the electrical contact between dissimilar metals which can result in galvanic corrosion.

SUMMARY

Composite specimens simulating fabricating practices used in the construction of the first Deep Submergence Rescue Vessel were exposed at mean tide level in the Pacific Ocean and under cyclic pressure loading in sea water to evaluate the efficacy of protective systems in alleviating galvanic and crevice corrosion. These specimens consisted of different combinations of alloys, fasteners, surface coatings, paint systems, sealing compounds and galvanic anodes.

This report presents the results of the evaluation of a set of specimens exposed for 371 days at mean tide level in the Pacific Ocean and of a set of specimens exposed to cyclic loading to 3,000 psi in sea water for 98 cycles.

Tidal Exposure

All specimens were moderately to heavily fouled with barnacles, mussels and tube worms.

The general appearance of this set of specimens was better than either the 3-month[1] or 6-month[2] sets due primarily to the lesser mechanical damage on this set of specimens.

There were paint failures on all the 6061-T6 aluminum alloy panels and on many of the 6061-T6 aluminum alloy strips. These failures ranged from mechanically caused failures of the paint system at the edges of the panel to peeling of the top coat of paint from the surfaces of the panel. When paint failures to bare metal occurred, corrosion of the base material was noted in most cases. Where no corrosion occurred, the paint failures were relatively recent.

There were no paint failures or blisters at the scribe marks intentionally made on anodized and painted 6061-T6 aluminum alloy panels. However, there were rust stains and blistering at the scribe marks made on painted HY140 steel specimens.

There were no general paint failures at the strip-panel faying surfaces during exposure. However, the top coat of paint was pulled from the panels when strips with the following sealants were removed:

1. One strip with DC-780 sealant
2. One strip with sprayed PVC sealant
3. Two strips with PR-1422 sealant
4. Two strips with PR-1527 sealant
5. Two strips with DC-93046 sealant

Paint failures under the strips at bolt holes on two panels were attributed to mechanical damage of the coating on assembly.

All but one of the sealants failed by losing their adhesion to fasteners. The percent failures of the sealants on the fastener heads are given below:

Sealant	Percent Failures
PR-1527	0
PR-1532	67
DC-780	80
PR-1422	100
DC-93046	100
Sprayed PVC	100
DC-11	100

The lack of failures on PR-1527 is partially due to its protection from abrasion by metal sleeves on one of the two panels on which it was used.

All sealants tested were effective in preventing crevice corrosion under painted strips fastened to painted panels. Paint coatings alone were not effective in preventing this attack due primarily to mechanical damage.

The 6Al-4V titanium alloy fasteners, A-286 stainless steel fasteners, type 304 stainless steel rivets, and Ni-Cu 400 alloy rivets were uncorroded. The 6061-T6 anodized aluminum alloy fasteners and 5052 aluminum alloy rivets were moderately to severely pitted where the DC-93046 sealant had failed.

The cadmium plated steel washers used with 6061-T6 aluminum alloy fasteners corroded when there were sealant failures, even when there was electrical contact between the washers and fasteners.

There were white corrosion products on the outer surfaces of the sleeves of the fasteners used on a 6061-T6 panel indicating that moisture had penetrated between the panel and sleeve.

Zinc anodes prevented generalized corrosion of bare and anodized 6061-T6 aluminum alloy. There were, however, areas of incipient crevice corrosion (<.001 inch) on a 6061-T6 aluminum alloy panel under 13V-11Cr-3Al titanium alloy strips indicating that the anodes were not completely effective in preventing crevice corrosion. Galvalum anodes prevented generalized corrosion of welded 7039 aluminum alloy and type 321 stainless steel. The consumption of the anodes was much greater (90% vs. 3%) when coupled to the stainless steel than when coupled to the aluminum alloy.

The paint systems used on HY140 steel had failed at scribe marks due to blistering and the metal underneath the failures had corroded. There were paint failures on a similarly painted and scribed 6061-T6 aluminum alloy panel but without underlying corrosion.

Pressure Vessel Tests

The specimens exposed to cyclic loading with sea water in pressure vessels, their component parts, the protective systems, the sealing compounds for filling crevices and coating fasteners, and the results of visual examinations after exposure are given in Table 2. Each specimen is discussed below.

The specimens from these tests were covered with superficial rust stains from the corrosion which occurred on the inside of the uncoated steel pressure vessel. The general condition of the specimens was better than any of the sets exposed in natural sea water; this was due primarily to the absence of fouling and the reduced amount of mechanical damage in the pressure vessel tests.

There were no paint failures on the panels except at the few areas of mechanical damage which occurred during loading of the specimens into the pressure vessel and where the paint was peeled from the panel

upon disassembly of the panel for inspection. The sealants on the fasteners in the pressure vessel tests were better than in the natural exposures, primarily due to the lack of mechanical damage and fouling. The percent failures of the sealants used on the heads of fasteners in the pressure vessel tests are given below:

Sealant	Percent Failure
PR-1527	0
DC-11	25
DC-780	40
PR-1422	50
PR-1532	67
Sprayed PVC	80
DC-93046	80

There was no general corrosion or pitting on the panel except when the panel was in contact with the steel pressure vessel. Crevice corrosion on unprotected faying surfaces, especially at bimetallic faying surfaces between titanium and aluminum where the attack was accelerated due to galvanic corrosion, was not prevented by galvanic protection using zinc anodes. The zinc anodes, however, arrested the pitting on the aluminum panels caused by contact with the steel pressure vessel.

There was no corrosion of the 5052 aluminum alloy, 304 stainless steel, or nickel-copper 400 alloy rivets. The 6061-T6 aluminum alloy, 6Al-4V titanium alloy, and A-286 stainless steel Hi-lok fasteners were uncorroded except for some slight corrosion of the 6061-T6 aluminum alloy fasteners under the failed DC-93046 sealant similar to that found in the natural exposure tests. The white corrosion products on the sleeves of the A-286 fasteners was indicative of water penetration due to sealant failure.

CONCLUSIONS

From Tidal Exposures

Paint coatings can be used to prevent galvanic and crevice corrosion as long as the coatings remain intact.

Sacrificial zinc anodes were satisfactory in preventing pitting and crevice corrosion of a 6061-T6 aluminum alloy composite panel but were not satisfactory for completely preventing galvanic-crevice corrosion under 13V-11Cr-3Al titanium alloy strips on a similar panel.

Sacrificial galvalum anodes were satisfactory for preventing corrosion of welded 7039 aluminum alloy and type 321 stainless steel.

Type 304 stainless steel rivets, nickel-copper 400 alloy rivets, and 6Al-4V titanium alloy fasteners are satisfactory for fabricating painted and galvanically protected aluminum alloy structures for periods of time of one year.

6061-T6 aluminum alloy fasteners and 5052 aluminum alloy rivets are satisfactory for fabricating aluminum alloy structures for periods of time of one year, except when used with DC-93046 sealing compound.

Sealing compounds DC-780, PR-1532, PR-1527, PR-1422, DC-93046, DC-11, and sprayed PVC can be expected to fail as fastener sealants during one year of exposure to sea water unless some protection from mechanical damage can be given. With protection from mechanical damage, these sealants are useful for periods of time of up to one year.

From Pressure Vessel Tests

In the pressure vessel tests there was no bio-fouling and only limited mechanical damage to the coatings and sealants. The samples exposed to such conditions showed that coatings and sealants are more effective in preventing corrosion when fouling and mechanical damage are kept at a minimum and that such coatings and sealants are not adversely affected by stagnant conditions such as experienced in these pressure vessel tests.

Sacrificial zinc anodes were successful in preventing pitting corrosion of 6061-T6 aluminum alloy and successful in arresting pitting on the alloy after the corrosion had proceeded to a considerable degree due to contact with the pressure vessel interior. 5052 aluminum alloy, type 304 stainless steel, and nickel-copper 400 alloy rivets; 6061-T6 aluminum alloy, A-286 stainless steel, and 6Al-4V titanium alloy fasteners are useable for fabrication of aluminum alloy structures exposed to conditions similar to those used in this test. 6061-T6 aluminum alloy fasteners are, however, vulnerable to attack when exposed under failed DC-93046 sealants.

Sealing compounds DC-11, DC-780, PR-1422, PR-1532, DC-93046, and sprayed PVC can be expected to fail as fastener sealants under the conditions of exposure experienced in the pressure vessel tests. Sealing compound PR-1527 is superior to the above as fastener sealants and can be expected to survive similar exposures. All sealants tested -- DC-11, DC-780, PR-1422, PR-1532, DC-93046, PR-1527, and sprayed PVC -- were successful in preventing crevice corrosion at painted faying surfaces.

REFERENCES

1. Naval Civil Engineering Laboratory. Technical Note N-1007: "Corrosion of DSRV materials in sea water - 3 months exposure," by Fred M. Reinhart, Port Hueneme, California, January 1969.

2. _____. Technical Note N-1037: "Corrosion of DSRV materials in sea water - 6 months exposure," by Fred M. Reinhart, Port Hueneme, California, July 1969.

Table 1. Specimens After 371 Days of Exposure in Tidewater

Specimen	Remarks
Panel G1C	6061-T6 aluminum alloy, anodized[1] and painted[2]; electrical contact between fasteners and Cadmium (Cd) plated steel washers; no electrical contact between fasteners and panel.
Front[3]	Few paint failures along edges of panel, much fouling.
Back	No paint failures, much fouling.
Strips	6061-T6 aluminum alloy, anodized[1] and painted[2]; HI-LOK 6061-T6 aluminum alloy fasteners, Cd plated steel washers.
#1	Paint failures on one end and on edges, much fouling.
Sealant	None.
Fasteners	No Corrosion of Al fasteners, edges, of Cd plated steel washers slightly corroded.
Faying Surfaces	No paint failure.
#2	Few paint failures on surface and edges, much fouling.
Sealant-DC-780	No failure, good adhesion.
Fasteners	No corrosion of Al fasteners or Cd plated steel washers.
Faying Surfaces	No paint failure.
#3	One small paint failure on edge, much fouling.
Sealant-PR-1532	No failure, good adhesion.
Fasteners	No corrosion of Al fasteners or Cd plated steel washers.

Table 1. (cont'd)

Specimen	Remarks
Faying Surfaces	No paint failure.
#4	One small paint failure on surface and one small paint failure on edge, much fouling.
Sealant-DC-93046	Sealant peeled from fasteners and washers, moderate adhesion to panel.
Fasteners	Nuts and bolts pitted, especially under sealant, Cd plated steel washers slightly corroded.
Faying Surfaces	No paint failure.
#5	Few paint failures along edges and three small paint failures on surfaces, much fouling.
Sealant-DC-11	Sealant gone from fasteners, no adhesion to panel.
Fasteners	No corrosion of Al fasteners, Cd plated steel washers slightly corroded.
Faying Surfaces	No paint failure.
#6	Few paint failures on edges and one paint failure on surface, much fouling.
Sealant-Sprayed PVC	Sealant gone from fasteners, no adhesion to panel.
Fasteners	No corrosion of Al fasteners, Cd plated steel washers slightly corroded.
Faying Surfaces	No paint failure.
Panel G2C	6061-T6 aluminum alloy, anodized[1] and painted[2]; no electrical contact between fasteners, strips or panel.

Table 1. (cont'd)

Specimen	Remarks
Front[3]	Paint failures on edges, especially at insulators, much fouling.
Back	Paint failures on edges, especially at insulators, much fouling.
Strips	6061-T6 aluminum alloy, anodized[1] and painted[2]; 5052 aluminum alloy rivets.
#1	Paint failure of top coat only; ½ sq. in., much fouling.
Sealant	None.
Fasteners	No corrosion.
Faying Surfaces	No paint failure.
#2	No paint failure, much fouling.
Sealant-PR-1527	No failures, good adhesion.
Fasteners	No corrosion.
Faying Surfaces	Top coat of paint stripped from panel on disassembly, no corrosion.
#3	No paint failure, much fouling.
Sealant PR-1422	Sealant gone on rivet heads[4]; cracked and partially gone on back, good adhesion.
Fasteners	No corrosion.
Faying Surfaces	Top coat of paint stripped from panel on disassembly, no corrosion.
#4	No paint failure, much fouling.
Sealant-DC-93046	Sealant gone on rivets.

Table 1. (cont'd)

Specimen	Remarks
Fasteners	Rivets badly pitted.
Faying Surfaces	Top coat of paint stripped from panel on disassembly, sea water penetration up to ¼", no corrosion, moderate adhesion.
#5	No paint failure, much fouling.
Sealant-DC-11	Sealant gone.
Fasteners	Dull, no corrosion.
Faying Surfaces	No paint failure, no adhesion, sealant intact under strip.
#6	Paint failure on edge, much fouling.
Sealant-Sprayed PVC	Sealant gone.
Fasteners	Dull, no corrosion.
Faying Surfaces	No paint failure, slight adhesion.
Panel G3C	6061-$T6_2$ aluminum alloy, anodized[1] and painted[2]; electrical contact between fasteners, strips and panel.
Front[3]	Paint failure at corners and at insulators with pitting at these areas, much fouling.
Back	Paint failure and blistering around fasteners on strips #1, 4, 5 & 6; pitting around fasteners on strip #4, much fouling.
Strips	6061-$T6_2$ aluminum alloy, anodized[1] and painted[2]; A-286 stainless steel fasterner with sleeves and crimp nuts.
#1	Paint failures and blistering at corners and around fasteners, much fouling, white corrosion products on sides of hole in panel and under blister adjacent to one bolt hole.

Table 1. (cont'd)

Specimen	Remarks
Sealant	None.
Fasteners	White corrosion products on sleeves, fasteners uncorroded.
Faying Surfaces	Paint failure with white corrosion products under blister next to bolt hole on strip.
#2	No paint failure, much fouling.
Sealant-DC-780	Sealant gone from head of one bolt, good adhesion.
Fasteners	White corrosion products on one sleeve, fasteners uncorroded.
Faying Surfaces	No paint failure.
#3	No paint failure, much fouling.
Sealant-PR-1532	Sealant cracked at end of nuts, good adhesion.
Fasteners	White corrosion products on sleeves, fasteners uncorroded.
Faying Surfaces	No paint failure.
#4	Paint failure with pitting underneath on one corner and adjacent to nuts, much fouling.
Sealant-DC-93046	Sealant gone from bolt heads, good adhesion.
Fasteners	White corrosion products on sleeves, fasteners uncorroded.
Faying Surfaces	Paint undercut with white corrosion products underneath around one bolt hole.

Table 1. (cont'd)

Specimen	Remarks
#5	Paint failures along edges and around bolt holes, much fouling.
Sealant-DC-11	Sealant gone on exposed areas, no adhesion.
Fasteners	White corrosion products on sleeves, fasteners uncorroded.
Faying Surfaces	No paint failure.
#6	Paint failures on edges, some blistering around bolt holes, much fouling.
Sealant-Sprayed PVC	Sealant gone from exposed areas, little adhesion.
Fasteners	White corrosion products on sleeves, fasteners uncorroded.
Faying Surfaces	One area of paint peeled upon disassembly, no corrosion underneath.
Panel G4C	6061-T6 aluminum alloy, anodized[1] and painted[2]; electrical contact between fasteners, strips and panel except between panel and strips #2, 5 & 6.
Front[3]	Top coat of paint peeled some areas of surface, paint failures with pitting underneath on edges at insulators, much fouling.
Back	Top coat of paint peeled some areas of surfaces, much fouling.
Strips	Ti-6Al-4V painted[2]; Ti-6Al-4V fasteners with aluminum alloy washers.
#1	Paint failures along edges, much fouling.
Sealant	None.

Table 1. (cont'd)

Specimen	Remarks
Fasteners	No corrosion, white corrosion products on washers.
Faying Surfaces	No paint failure.
#2	Paint failures at edges, much fouling.
Sealant-PR-1527	Sealant intact, holding rings rusted, good adhesion.
Fasteners	No corrosion, yellow corrosion products on washers one side.
Faying Surfaces	Top coat of paint peeled from panel on disassembly.
#3	Paint failures at edges, much fouling.
Sealant-PR-1422	Sealant failed on heads of fasteners, good adhesion.
Fasteners	No corrosion, white corrosion products on washers.
Faying Surfaces	Top coat of paint peeled from panel on disassembly.
#4	Paint failures at edges, much fouling.
Sealant-DC-93046	Sealant gone from exposed areas, good adhesion.
Fasteners	No corrosion, white corrosion products on washers.
Faying Surfaces	Top coat of paint peeled from panel on disassembly.
#5	Paint failures along edges, much fouling.
Sealant-DC-11	Sealant gone from exposed areas, no adhesion.

Table 1. (cont'd)

Specimen	Remarks
Fasteners	No corrosion, white corrosion products on washers.
Faying Surfaces	No paint failure.
#6	Paint failures along edges, much fouling.
Sealant-Sprayed PVC	Sealant gone from exposed areas, no adhesion.
Fasteners	No corrosion, white corrosion products on washers.
Faying Surfaces	No paint failure.
Panel G5C	6061-T6 aluminum alloy, anodized[1] and painted[2], electrical contact between fasteners, strips and panel.
Front[3]	Paint failures on edges and at insulators with pitting underneath, one corner gone, blistering around strip #1 with pitting underneath, much fouling.
Back	Paint failures at edges and insulators with up to ½" wide corrosion area at insulators, much fouling.
Strips	Ti-6Al-4V painted[2]; A-286 stainless steel fasteners, Cd plated steel washers under nuts.
#1	Paint failures on edges, much fouling.
Sealant	None.
Fasteners	No corrosion, washers rusted.
Faying Surfaces	Paint failed around bolt holes, white corrosion products at failures and in bolt holes.

Table 1. (cont'd)

Specimen	Remarks
#2	Paint failures on edges, much fouling.
Sealant-DC-780	Rust on washers under sealant, fair adhesion.
Fasteners	No corrosion, washers rusted.
Faying Surfaces	Top coat of paint peeled from strip on disassembly.
#3	Paint failures on edges, much fouling.
Sealant-PR-1532	Rust on washers under sealant, good adhesion.
Fasteners	No corrosion, washers rusted.
Faying Surfaces	No paint failure.
#4	Paint failures on edges, much fouling.
Sealant-DC-93046	Rust on washers under sealant, good adhesion.
Fasteners	No corrosion, washers rusted.
Faying Surfaces	No paint failures.
#5	Paint failures on edges, much fouling.
Sealant-DC-11	Sealant gone from exposed areas, no adhesion.
Fasteners	No corrosion, washers rusted.
Faying Surfaces	No paint failures.
#6	Paint failures on edges, much fouling.
Sealant-Sprayed PVC	Sealant gone from exposed areas, no adhesion.
Fasteners	No corrosion, washers rusted.

Table 1. (cont'd)

Specimen	Remarks
Faying Surfaces	No paint failures.
Panel G8C	6061-T6 aluminum alloy, anodized[1]; electrical contact between rivets, panel, strips and attached zinc anode.
Front[3]	90% of anodized coating gone, nearly intact under strips, etching, moderate fouling.
Back	95% of anodized coating gone, etched, moderate fouling.
Strips	6061-T6 aluminum alloy, anodized[1]; type 304 stainless steel and nickel-copper 400 alloy rivets.
#1	Anodized coating gone, etched, moderate fouling.
Fasteners	Type 304 rivets uncorroded.
Faying Surfaces	Anodized coating gone and white corrosion products up to ¼" under strip, rest of anodized coating under strip intact.
#2	Anodized coating gone, etched, moderate fouling.
Fasteners	Type 304 rivets uncorroded.
Faying Surfaces	Anodized coating gone and white corrosion products up to 1/8" under strip, rest of anodized coating under strip intact.
#3	Anodized coating gone, etched, moderate fouling.
Fasteners	Type 304 rivets uncorroded.

Table 1. (cont'd)

Specimen	Remarks
Faying Surface	Anodized coating gone and white corrosion products up to 1/8" under strip, rest of anodized coating under strip intact.
#4	Anodized coating gone, etched, moderate fouling.
Fasteners	Nickel-copper 400 alloy rivets uncorroded.
Faying Surfaces	Anodized coatings gone and white corrosion products up to 1/16" under strip, rest of anodized coating under strip intact.
#5	Anodized coating gone, etched, moderate fouling.
Fasteners	Nickel-copper 400 alloy rivets uncorroded.
Faying Surfaces	Anodized coating gone and white corrosion products up to 1/16" under strip, rest of anodized coating under strip intact.
#6	Anodized coating gone, etched moderate fouling.
Fasteners	Nickel-copper 400 alloy rivets uncorroded.
Faying Surfaces	Anodized coating gone and white corrosion products up to 1/16" under strip, rest of anodized coating under strip intact.
Anode	5% consumed with a slight groove next to panel, anodized coating intact under anode.
Panel G8G	Bare 6061-T6, aluminum alloy; electrical contact between rivets, panel, strips and attached zinc anode.
Front[3]	Etched, dark gray, moderate fouling.
Back	Etched, dark gray, moderate fouling.

Table 1. (cont'd)

Specimen	Remarks
Strips	Bare Ti-13V-11Cr-3Al, rivets type 304 stainless steel and nickel-copper 400 alloy.
#1	No corrosion, moderate fouling.
Fasteners	Type 304 rivets uncorroded.
Faying Surfaces	White corrosion products, panel etched.
#2	No corrosion, moderate fouling.
Fasteners	Type 304 rivets uncorroded.
Faying Surfaces	White corrosion products, panel etched.
#3	No corrosion, moderate fouling.
Fasteners	Type 304 rivets uncorroded.
Faying Surfaces	White corrosion products, panel etched.
#4	No corrosion, moderate fouling.
Fasteners	Nickel-copper 400 alloy rivets uncorroded.
Faying Surfaces	White corrosion products, panel etched.
#5	No corrosion, moderate fouling.
Fasteners	Nickel-copper 400 alloy rivets uncorroded.
Faying Surfaces	White corrosion products, panel etched.
#6	No corrosion, moderate fouling.
Fasteners	Nickel-copper 400 alloy rivets uncorroded.
Faying Surfaces	White corrosion products, panel etched.
Anode	10% consumed with a slight groove next to panel, no corrosion under anode.

Table 1. (cont'd)

Specimen	Remarks
Panel G9C	6061-T6 aluminum alloy, anodized[1] and painted[2]; no electrical contact between panel, strips and fasteners.
Front[3]	Few paint failures along edges, much fouling.
Back	Few paint failures along edges, much fouling.
Strips	Ti-13V-11Cr-3Al, 18-8 stainless steel cap screws, Ag plated nuts, delrin strips, sleeves and washers.
#1	No corrosion, much fouling.
Sealant-DC-780	Failure on fasteners, good adhesion.
Fasteners	Rust stains on bolts and nuts without noticeable pitting.
Faying Surfaces	No corrosion.
#2	No corrosion, much fouling.
Sealant DC-780	Failure on fasteners, good adhesion.
Fasteners	Rust stains on bolts and nuts with noticeable pitting.
Faying Surfaces	No corrosion.
Panel #2	7039 aluminum alloy, longitudinal TIG butt weld with 5039 filler metal, 3" dia circular TIG weld with 5356 filler metal, electrical contact between panel and attached galvalum anode.
Panel	No corrosion, much fouling
Anode	Minor pitting % consumed.

Table 1. (cont'd)

Specimen	Remarks
Panel #4	7039 aluminum alloy, longitudinal MIG butt weld with 5039 filler metal, electrical contact between panel and attached galvalum anode.
Panel	No corrosion, much fouling.
Anode	Minor pitting 3% consumed.
Panel #6	Type 321 stainless steel, transverse TIG butt weld with 347 filler metal, electrical contact between panel and attached galvalum anode.
Panel	No corrosion, much fouling.
Anode	Anode 90% consumed.
Panel #7	Type 321 stainless steel with transverse TIG butt weld, no filler metal electrical contact between panel and attached galvalum anode.
Panel	No corrosion, much fouling.
Anode	90% consumed.
Panel #8	6061-$T6_2$ aluminum alloy anodized[1] and painted[2] (6 mils), double X scribe marks to bare metal.
Panel	Paint failure at bottom edge with attendant corrosion, no blistering or paint failure at scribe marks, much fouling.
Panel #9	6061-$T6_2$ aluminum alloy, anodized[1] and painted[2] (6 mils) single X scribe mark to bare metal.
Panel	Paint failure from abrasion on bottom edge, no corrosion at scribe marks, much fouling.

Table 1. (cont'd)

Specimen	Remarks
Panel #12	HY 140 steel, painted (6 mils) single X scribe mark to bare metal.
Panel	Few paint failures with rusting along edges and on surface with scribe marks, blisters and rust stains at scribe marks, no paint failures on surface opposite scribe marks, much fouling.
Panel #13	HY 140 steel, painted (8 mils), single X scribe mark to bare metal.
Panel	Paint failures along edges and on surface with attendant rusting, paint failures and rusting at scribe marks, much fouling.

Footnotes:

1. Chromic acid anodized.

2. Paint system:

   Wash primer - 1 coat phosphoneal
   Primer - 1 coat epoxy and 1 coat polyurethane
   Topcoat - 2 coats color coded polyurethane

3. Surface with strips attached to it.

4. Ends of rivets on strip side.

Table 2. Specimens After 98 Cycles in Pressure Vessel

Specimen	Remarks
Panel G1D	6061-T6 aluminum alloy, anodized[1] and painted[2]; electrical contact between fasteners and Cd plated steel washers; no electrical contact between fasteners and panel.
Front[3]	Superficial rust stains, no paint failures.
Back	Superficial rust stains, no paint failures.
Strips	6061-T6 aluminum alloy, anodized[1] and painted[2]; HI-LOK 6061-T6 aluminum alloy anodized fasteners, Cd plated steel washers.
#1	No paint failures, superficial rust stains.
Sealant	None.
Fasteners	Light corrosion of bolts at nut ends.
Faying Surfaces	No paint failure.
#2	No paint failures, superficial rust stains.
Sealant DC-780	No failure, good adhesion.
Fasteners	No corrosion.
Faying Surfaces	No paint failure.
#3	No paint failures, superficial rust stains.
Sealant PR-1532	No failure, good adhesion.
Fasteners	No corrosion.
Faying Surfaces	No paint failure.
#4	No paint failure, superficial rust stains.
Sealant DC-93046	Sealant separated from fasteners, good adhesion at faying surfaces.
Fasteners	Some attack of bolt under sealant, nut intact, washers uncorroded.

Table 2. (Cont'd)

Specimen	Remarks
Faying Surfaces	No paint failure.
#5	No paint failure, superficial rust stains.
Sealant DC-11	No failure, no adhesion.
Fasteners	No corrosion.
Faying Surfaces	No paint failure.
#6	No paint failure, superficial rust stains.
Sealant-Sprayed PVC	No failure, little adhesion.
Fasteners	Light corrosion bolts near nuts.
Faying Surfaces	No paint failure.
Panel G2D	6061-T6 aluminum alloy, anodized[1] and painted[2]; no electrical contact between fasteners, strips or panel.
Front[3]	Paint abrasion two lower corners, fixed with DC-780, no corrosion, superficial rust stains.
Back	Superficial rust stains.
Strips	6061-T6 aluminum alloy, anodized[1] and painted[2]; 5052 aluminum alloy rivets.
#1	No paint failure, superficial rust stains.
Sealant	None.
Fasteners	No corrosion.
Faying Surfaces	No paint failure.
#2	No paint failure, superficial rust stains.
Sealant PR-1527	No failure, good adhesion.

Table 2. (Cont'd)

Specimen	Remarks
Fasteners	No corrosion.
Faying Surfaces	Top coat of paint peeled on disassembly, no corrosion.
#3	No paint failures, superficial rust stains.
Sealant PR-1422	No failure, good adhesion.
Fasteners	No corrosion.
Faying Surfaces	Top coat of paint peeled on disassembly, no corrosion.
#4	No paint failure, superficial rust stains.
Sealant DC-93046	No failure, good adhesion.
Fasteners	No corrosion.
Faying Surfaces	Top coat of paint peeled on disassembly, no corrosion.
#5	No paint failure, superficial rust stains.
Sealant DC-11	No failure, no adhesion.
Fasteners	No corrosion.
Faying Surfaces	No paint failure.
#6	No paint failure, superficial rust stains.
Sealant-Sprayed PVC	No failure, little adhesion.
Fasteners	No corrosion.
Faying Surfaces	No paint failure.
Panel G3D	6061-T6 aluminum alloy, anodized[1] and painted[2]; electrical contact between fasteners, strips and panel.

Table 2. (Cont'd)

Specimen	Remarks
Front[3]	Paint failure on one corner with light corrosion underneath. Superficial rust stains.
Back	Superficial rust stains.
Strips	6061-T6 aluminum alloy, anodized[1] and painted[2]; A-286 stainless steel fasteners with sleeves and crimp nuts.
#1	No paint failure, superficial rust stains.
Sealant	None.
Fasteners	White corrosion products on sleeves, no corrosion of fasteners.
Faying Surfaces	No paint failures.
#2	No paint failure, superficial rust stains.
Sealant DC-780	Sealant failed at fastener heads, white corrosion products underneath sealant. Good adhesion.
Fasteners	White corrosion products on sleeves and bolt heads, no corrosion of fasteners.
Faying Surfaces	No paint failure.
#3	No paint failure, superficial rust stains.
Sealant PR-1532	No failure, good adhesion.
Fasteners	White corrosion products on sleeves, no corrosion of fasteners.
Faying Surfaces	No paint failure.
#4	No paint failure, superficial rust stains.
Sealant DC-93046	Sealant failed at fastener heads with white corrosion products underneath sealant. Good adhesion.

Table 2. (Cont'd)

Specimen	Remarks
Fasteners	White corrosion products on sleeves, no corrosion on fasteners.
Faying Surfaces	No paint failure.
#5	No paint failure, superficial rust stains.
Sealant DC-11	No failure, no adhesion.
Fasteners	No corrosion.
Faying Surfaces	No paint failures.
#6	No paint failures, superficial rust stains.
Sealant-Sprayed PVC	Sealant failed at fastener heads with white corrosion products underneath sealant, little adhesion.
Fasteners	White corrosion products on sleeves, no corrosion on fasteners.
Faying Surfaces	No paint failures.
Panel G4D	6061-T6 aluminum alloy, anodized[1] and painted[2]; electrical contact between fasteners, strips and panel.
Front[3]	No paint failures, superficial rust stains.
Back	No paint failures, superficial rust stains.
Strips	6Al-4V Titanium alloy painted[2]; 6Al-4V titanium alloy fasteners with aluminum alloy washers.
#1	No paint failures, superficial rust stains.
Sealant	None.
Fasteners	No corrosion fasteners, white corrosion of washers.
Faying Surfaces	Top coat of paint stripped on disassembly, no corrosion.

Table 2. (Cont'd)

Specimen	Remarks
#2	No paint failures, superficial rust stains.
Sealant PR-1527	No failure, good adhesion.
Fasteners	No corrosion.
Faying Surfaces	Top coat of paint stripped on disassembly, no corrosion.
#3	No paint failures, superficial rust stains.
Sealant PR-1422	Sealant failed slightly at fastener heads, good adhesion.
Fasteners	No corrosion.
Faying Surfaces	Top coat of paint stripped on disassembly, no corrosion.
#4	No paint failures, superficial rust stains.
Sealant DC-93046	Sealant failed at fasteners, good adhesion.
Fasteners	No corrosion, white corrosion products on washers.
Faying Surfaces	To coat of paint peeled on disassembly, no corrosion.
#5	No paint failure, superficial rust stains.
Sealant DC-11	Failure at fasteners, no adhesion.
Fasteners	No corrosion, white corrosion products on washers.
Faying Surfaces	No paint failures.
#6	No paint failures, superficial rust stains.
Sealant-Sprayed PVC	Failure at fasteners, little adhesion.
Fasteners	No corrosion, white corrosion products on washers.
Faying Surfaces	No paint failures.

Table 2. (Cont'd)

Specimen	Remarks
Panel G5D	6061-T6 aluminum alloy, anodized[1] and painted[2]; electrical contact between fasteners, strips and panel.
Front[3]	Paint failures with undercutting corrosion at unused holes between strips #1 and #2. Superficial rust stains.
Back	Rust bleeding from fasteners on strips #1, 2, 3, 4 and 6.
Strips	6Al-4V titanium alloy painted[2]; A-286 stainless steel fasteners, Cd plated steel washers under nuts.
#1	No paint failures, superficial rust stains.
Sealant	None.
Fasteners	No corrosion, washers rusted.
Faying Surfaces	No paint failure.
#2	No paint failure, superficial rust stains.
Sealant DC-780	Sealant failed at fasteners. Good adhesion.
Fasteners	No corrosion, washers rusted.
Faying Surfaces	No paint failure.
#3	No paint failure, superficial rust stains.
Sealant PR-1532	Sealant failed at fasteners. Good adhesion.
Fasteners	No corrosion, washers rusted.
Faying Surfaces	No paint failure.
#4	No paint failure, superficial rust stains.
Sealant DC-93046	Sealant failed at fasteners. Good adhesion.

Table 2. (Cont'd)

Specimen	Remarks
Fasteners	No corrosion, washers rusted.
Faying Surfaces	No paint failure.
#5	No paint failure, superficial rust stains.
Sealant DC-11	No failure, no adhesion.
Fasteners	No corrosion, washers only very slightly rusted.
Faying Surfaces	No paint failures.
#6	No paint failure, superficial rust stains.
Sealant-Sprayed PVC	Sealant failed at fasteners. Slight adhesion.
Fasteners	No corrosion, washers rusted.
Faying Surfaces	No paint failures.
Panel G8D	6061-T6 aluminum alloy, anodized[1]; electrical contact between rivets, panel, strips and attached zinc anode.
Front[3]	Light superficial rust stains. Pitting at corners.
Back	Light superficial rust stains, light white corrosion products around fasteners, scattered shallow pitting.
Strips	6061-T6 aluminum alloy, anodized[1]; type 304 stainless steel and nickel-copper 400 alloy rivets.
#1	Superficial rust stains, some pitting, light white corrosion products around fasteners
Fasteners	Type 304 rivets uncorroded.
Faying Surfaces	Scattered white corrosion products and light superficial rust stains.

Table 2. (Cont'd)

Specimen	Remarks
#2	Superficial rust stains, some pitting, light white corrosion products around fasteners.
Fasteners	Type 304 rivets uncorroded.
Faying Surfaces	Scattered white corrosion products and light superficial rust stains.
#3	Superficial rust stains, light white corrosion products around fasteners.
Fasteners	Type 304 rivets uncorroded.
Faying Surfaces	Scattered white corrosion products and light superficial rust stains.
#4	Superficial rust stains, light white corrosion products around fasteners.
Fasteners	Nickel-copper 400 alloy rivets uncorroded.
Faying Surfaces	Scattered white corrosion products and light superficial rust stains.
#5	Superficial rust stains, light white corrosion products around fasteners.
Fasteners	Nickel-copper 400 alloy rivets uncorroded.
Faying Surfaces	Scattered white corrosion products and light superficial rust stains.
#6	Superficial rust stains, light white corrosion products around fasteners.
Fasteners	Nickel-copper 400 alloy rivets uncorroded.
Faying Surfaces	Scattered white corrosion products and light superficial rust stains.
Anode	No visible consumption.
Panel G8H	Bare 6061-T6 aluminum alloy, electrical contact between panel, strips, rivets and attached zinc anode.

Table 2. (Cont'd)

Specimen	Remarks
Front[3]	Scattered white corrosion products, heaviest at edges of strips. Superficial rust stains.
Back	Scattered white corrosion products. Superficial rust stains.
Strips	13V-11Cr-3Al titanium alloy, strips, type 304 stainless steel and nickel-copper 400 alloy rivets.
#1	No corrosion.
Fasteners	Type 304 rivets uncorroded.
Faying Surfaces	White corrosion products and moderate incipient pitting.
#2	No corrosion.
Fasteners	Type 304 rivets uncorroded.
Faying Surfaces	White corrosion products and moderate incipient pitting.
#3	No corrosion.
Fasteners	Type 304 rivets uncorroded.
Faying Surfaces	White corrosion products and moderate incipient pitting.
#4	No corrosion.
Fasteners	Nickel-copper 400 alloy rivets uncorroded.
Faying Surfaces	White corrosion products and moderate incipient pitting.
#5	No corrosion.
Fasteners	Nickel-copper 400 alloy rivets uncorroded.
Faying Surfaces	White corrosion products and light incipient pitting.

Table 2. (Cont'd)

Specimen	Remarks
#6	No corrosion.
Fasteners	Nickel-copper 400 alloy rivets uncorroded.
Faying Surfaces	White corrosion products and very light incipient pitting.
Anode	No visible consumption.
Panel G9D	6061-T6 aluminum alloy, anodized[1] and painted[2]; no electrical contact between panel, strips and fasteners.
Front[3]	Light superficial rust staining.
Back	Light superficial rust staining.
Strips	11V-11Cr-3Al titanium alloy, 18-8 stainless steel cap screws, Ag plated nuts, delrin strips, sleeves and washers.
#1	No paint failure, light superficial rust staining.
Sealant DC-780	No failures, good adhesion.
Fasteners	No corrosion.
Faying Surfaces	No paint failures.
#2	No paint failure, light superficial rust stains.
Sealant DC-780	No failures, good adhesion.
Fasteners	No corrosion.
Faying Surfaces	No paint failures.

Footnotes:

1 Chromic acid anodized.
2 Paint System:

Wash Primer - 1 coat phosphoneal
Primer - 1 coat epoxy and 1 coat polyurethane
Top coat - 2 coats color coded polyurethane

3 Surface with strips attached to it.
4 Ends of rivets on strip side.

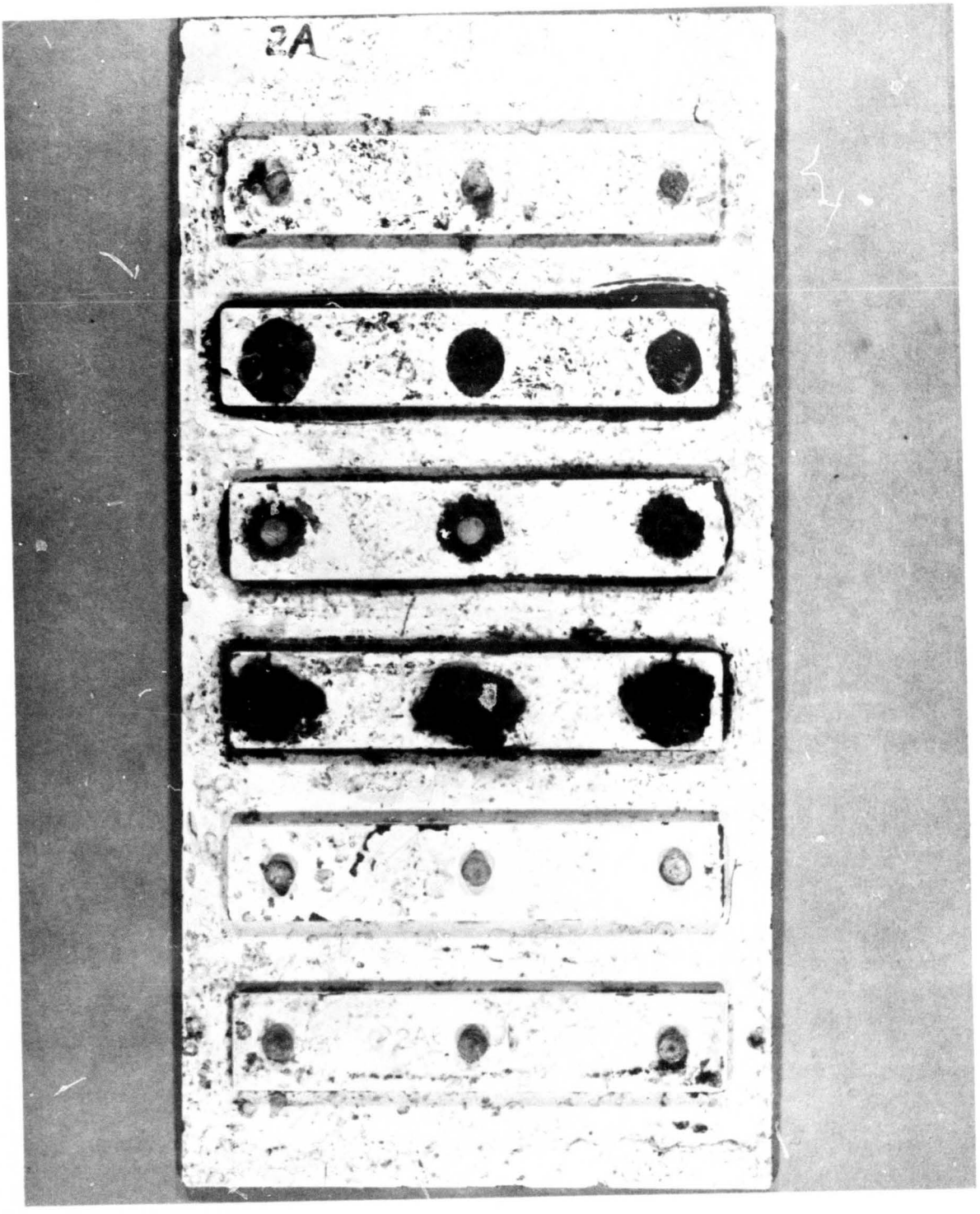

Figure 1. Exposed specimen showing general layout.

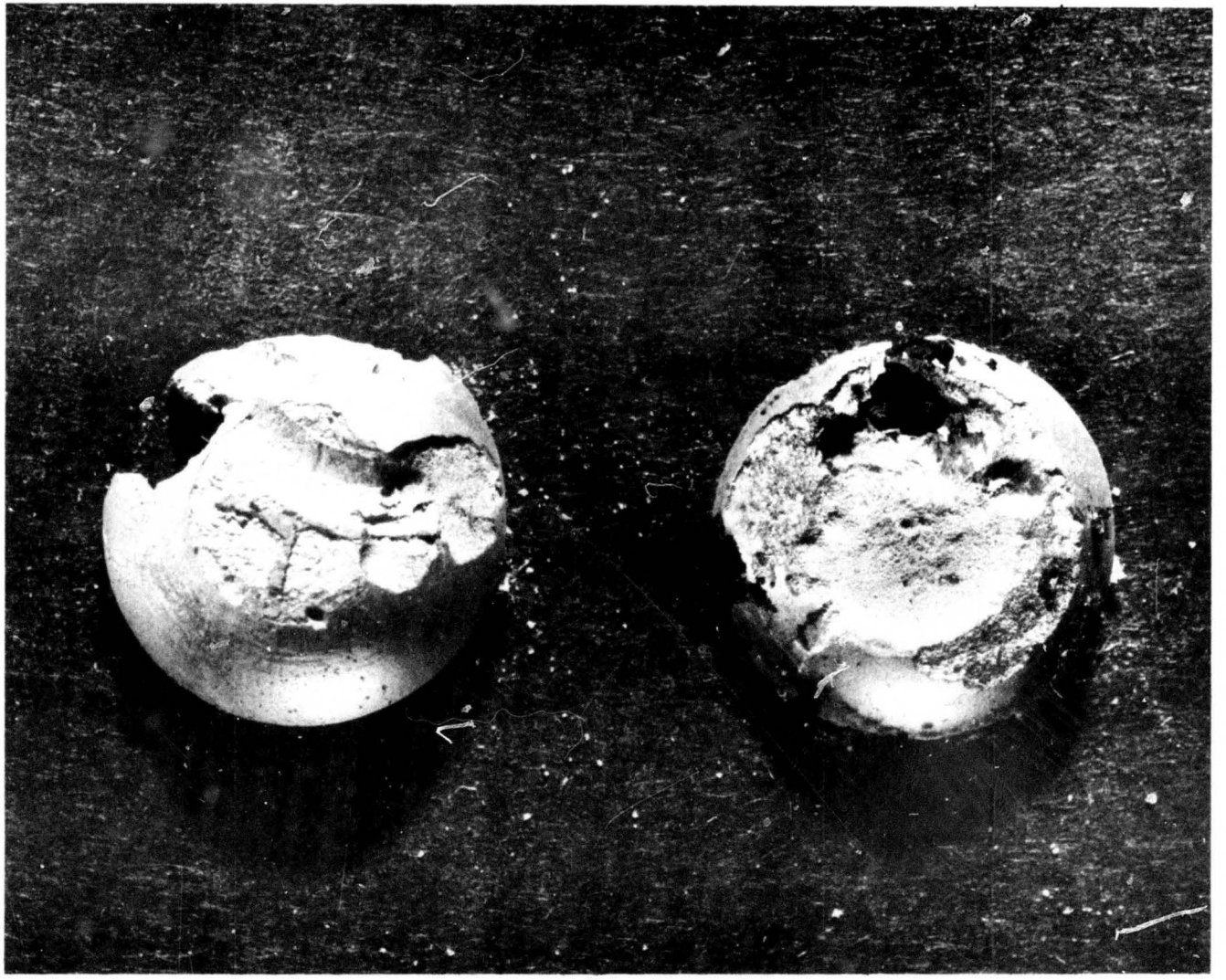

Figure 2. Severely pitted 5052 aluminum alloy rivets exposed under failed DC-93046 sealant.

Figure 3. Arrested pitting on anodized 6061-T6 strip. Initiated by contact with steel vessel.

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13. ABSTRACT

In order to evaluate specific corrosion problems involved in the design of the DSRV (Deep Submergence Rescue Vessel), a corrosion test program was initiated to determine: (1) the effects of galvanic and crevice corrosion on selected combinations of metals, and (2) the efficacy of selected paint coatings, sealing compounds and galvanic anodes for mitigating corrosion, crevice corrosion and galvanic corrosion. Composite specimens representative of proposed DSRV construction materials and methods were exposed for 370 days at mean tide level in sea water and to cyclic exposure to pressurized sea water. This report presents an evaluation of these composite specimens after exposure.

14. KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
Corrosion						
Sea Water						
Metals						
Galvanic corrosion						
Concentration cell corrosion						
Protective coatings						
Paints						
Coatings						
Sealants						
Construction materials						
Exposure						
Galvanic anodes						
Cyclic pressure						